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ADP014152

TITLE: Virtual Development and Integration of Advanced Aerospace Systems: Alenia Aeronautics Experience

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TITLE: Reduction of Military Vehicle Acquisition Time and Cost through Advanced Modelling and Virtual Simulation [La reduction des couts et des delais d'acquisition des vehicules militaires par la modelisation avancee et la simulation de produit virtuel]

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Virtual Development and Integration of Advanced Aerospace Systems: Alenia Aeronautics Experience

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1. Introduction

The Italian Aerospace Industry has been involved, over the last few years, in a significant evolution which applies both to design and production processes and to international co-operation with a consequent improvement of its product and services requiring new professional roles and skill.

In fact, the development of an aeronautical project is based on a specific approach in the technique-scientific disciplines management: the Concurrent Engineering. According to this methodology, the product is developed with a multidisciplinary and integrated framework, having as objective the optimization of the whole aircraft system. A number of examples demonstrates that this approach allowed to reach dramatic results in reduction of development time and cost.

Practical experience of Concurrent Engineering can be combined with up-to-date Information Technology to exploit the capability for enhanced design and manufacturing processes. In fact, the management of advanced project requires an integrated process management with the necessity of defining specific methods and tools that allow to verify in advance all possible problems of the product in particular with virtual product management (Digital Mock-Up) and with the integrated product data management (Product Data Management, Enterprise Resource Management).

Moreover, this process has to be managed in a “Synthetic Environment” that is a combination or “federation” between a number of models, simulations and real equipment, possibly including human operators in the loop, into a common representation of the world. Using state-of-the-art networking technology, this environment is used to provide consistency and concurrency across previously isolated processes. The use of such networked systems, either within a single company or among partner companies, is also an effective mean of developing co-operative effort within teams, especially where a Concurrent Engineering approach is adopted.

Alenia Aeronautica has gained a solid and consolidated experience in this field within a number of past and ongoing programs. This paper will describe this experience, and will tackle the methods which are used and planned to be used, so to cross-transfer the above experience to other military as well as civilian programs.

This document is organised as follows: a brief description of the Concurrent Engineering concept as used for developing aeronautical programmes is provided first. An illustration of tools presently used to implement the above concept is next, along with examples of its application with respect to some ongoing programmes. Synthetic Environment development is then introduced; current activities taking place at the Flight Simulation Department aimed at developing a kernel simulation Synthetic Environment are described. Finally the path for joint Concurrent Engineering and Synthetic Environment development is explored. Three noteworthy but more general projects in line with this vision are the participation in European funded projects on Concurrent Engineering, Distributed and Integrated Configuration Management Process and Synthetic Environment.

2. Concurrent Engineering

The Concurrent Engineering (CE) is a systematic approach for the integrated definition of the product with all manufacturing related processes. This approach requires to take into account of all elements of the Product Life Cycle since the beginning of the project, i.e. from the concept to the disposal.

Paper presented at the RTO AVT Symposium on “Reduction of Military Vehicle Acquisition Time and Cost through Advanced Modelling and Virtual Simulation”, held in Paris, France, 22-25 April 2002, and published in RTO-MP-089.

In the aeronautical product development this means:

- to organise the development of the Product/Process in an integrated and simultaneous way in order to reduce time and minimise the changes verifying the feasibility of functionality/components before the first release;
- to satisfy the qualitative requirements of the final product and to reduce Costs in the In Service Phase;
- to guarantee the respect of activity schedule.

The CE requires the involvement of Pre-Design, all Design Disciplines, Production, Procurement, Product Support, Quality and Planning/Control, allowing each member of a specific Function to develop his activities taking into account in each project phase all elements of the Product Life Cycle.

The 3 key elements of Concurrent Engineering are:

- Organisation
- Methods
- Tools

2.1 Organisation

Organizational aspects are strictly related to the CE approach: a key factor of CE is the Design Built Team.

A Design Built Team (DBT) is an integrated, multifunctional and sometimes also multipartner team defined in a different composition in relation to a specific phase of the program that is transversal to the hierarchical organisation structure and that exists only for the time required to the achievement of specific objectives.

The DBT's are essential for the process, allowing inter-functional communication and the inclusion in the project of all disciplines requirements before the product release. DBT's Inter-functionality and multi-disciplinarity guarantee that each Function has a global visibility of all activities performed in the different Phases/Sub-phases of the Process.

Moreover, the Integrated Schedule defined in co-operation by different Functions and the Continuous Information Sharing allows to reduce errors, changes and repairs, increasing the Productivity.

2.2 Methods

Methods are standards, rules and recommended practices (applicable at international, government and company level) which have to be followed for appropriate work of the CE.

The "Best Practices" of CE are based on the implementation of an Integrated Process Management that allows to manage activities not only as a specific aspect of a discipline (figure 1) but also with transversal and multidisciplinary process (figure 2) allowing a better and integrated vision of the product.

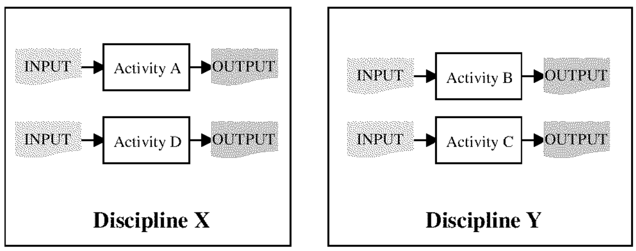

Fig. 1 – Process Management by discipline

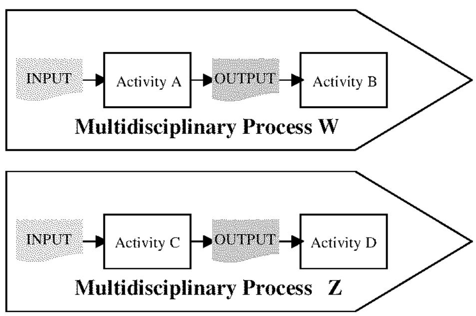

Fig. 2 – Integrated Process Management

2.3 Tools

Information Technology covers a key role in the support of the Concurrent Engineering approach. The tools that are supporting the digital and sharing of integrated data within a multifunctional, multidisciplinary and multipartner approach are based on Computer Aided Application (CAE, CAD, CAM and DMU), Product Data Management (PDM) application, Communication tools, Network, Synthetic Environment, etc..

In this paper we will concentrate in describing tools related to DMU, PDM and Synthetic Environment area.

3. Alenia experience in Virtual Product Management

3.1 PDM and DMU Introduction

PDM is a tool which assures the integration of the information defined by different Functions and controls the information evolution along the product lifecycle.

One of the most important PDM tasks is to handle the Product Structure by means of a full Configuration Management. In other words, it assures the management of all product configurations, in several views (as required, as designed, as planned, as built, etc.), and the distribution of information to other applications.

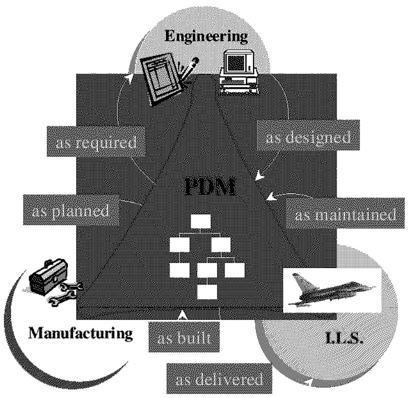

Fig. 3 – PDM for Product Configuration Management

The user access to applications and data is done through PDM. The database shared among applications is made-up with product and processes data. In other words PDM enables data access and data sharing in different departments and sites.

With PDM it is possible to manage the correct configuration of the product, as for physical, electrical and software items, together with standard parts and equipment.

The main features of PDM, as described in the following chapters, are:

- Multiple View Management
- Change Process Management
- Advanced Information Management
- Multi-site PDM Implementation
- Configured Digital Mock-Up
- Visualisation
- Technical Publication and Training

The adopted Alenia PDM tool is ENOVIA Product Manager Version 3.4 (PM) marketed and customised for Alenia by IBM. The CAD/CAM tool adopted for Eurofighter Typhoon and A380 programs is CATIA Version 4.2.2.1 which numbers among its packages the CATIA Data - Product Manager Integration (CDP).

CATIA is a Dassault Systèmes product, marketed by IBM. The Visualiser used in our Company to allow the access to CAD data also to the users simply equipped with a PC is the VisMockUp tool, Version 3.1, of UGS-EAI. This tool was customised by EAI to interface it with PM by means of an interface named "PM Agent".

One of the main added value of Alenia PDM implementation is the connection with CAD world, that is the Configured Digital Mock-Up, so that it is possible to retrieve and visualise the Digital Mock-Up of the requested configuration. The views covered by actual PDM are just the as designed and the as planned; in addition there are some information about the as built view. The use of the tool has been extended to all Alenia sites in 2001.

The first PDM project has been implemented for the Eurofighter Typhoon Project. The implementation of PDM for the new program A380 has been based on the complete reuse of Eurofighter Typhoon PDM innovative functionality and architecture with some customisation needed in order to be compliant with the civil aircraft process and the Airbus France requirements.

In this paper, we will describe the Alenia state of art/experience mainly focussing on Engineering activities.

3.2 Multiple View Management

In Alenia PDM system, in the product structure are managed different kinds of Part Numbers (P/Ns):

- Detail: a part which can not be split in other finished Parts, with its own CAD model, with additional information, such as materials codes and protective treatments, for the production.
- Assembly: a collection of parts forming a self-contained, independently mounted unit. Finished and storable Part composed by two or more Parts (Details or other Assemblies), with its own CAD model.
- Installation: a part composed by two or more parts (Details, Assemblies or other Installations), which can be realised only during the manufacturing of an higher level Assembly, with its own CAD model.
- Standard parts: parts, with or without CAD models, bought by the company from a supplier.

The designed parts pass through a process of validation with a formal signature and with a workflow that involves different departments in the company, not only in Engineering, so that all the information linked to a part are validated.

The two views of the product structure, Engineering (as-designed) and Manufacturing (as-planned) are both contained in the Alenia PDM system and are strictly connected. In particular the Manufacturing Bill of Material (BoM) is obtained from the Engineering one through the "Accept" process.

When designers have finished their activities on a set of Part Numbers organized in a single Engineering Release Authority (ERA), this Engineering structure is released (through a validation workflow managed by the system) and becomes available for Manufacturing acceptance. The acceptance of the ERA by Manufacturing users makes the new Engineering Structure integrated in the already created Manufacturing BoM, saving the pre-existent Manufacturing data and indicating if some specific actions are needed to guarantee structure coherency.

In the Manufacturing View are made all the Manufacturing activities in order to consolidate the Manufacturing BoM: creation of only Manufacturing Part Number, insert of data and documents, restructuring actions, etc.. When the structure is ready it is made effective and sent to the Material Resources Planning tool.

3.3 Change process management

In the Alenia PDM system, the Change Process is managed with a specific workflow. The change of different Part Numbers is managed with a change document that is called Request For Alteration (RFA), when the request is originated by Engineering, and Manufacturing Change Alteration (MCA), when the request is originated by the Manufacturing. These documents are managed through PDM, along all their lifecycle, their different status and their different issues.

Moreover, with the Alenia Change Process workflow (figure 4) it is managed the information concerning the point in the production phase in which the change has to be verified and embodied, and the indication of the correct embodiment.

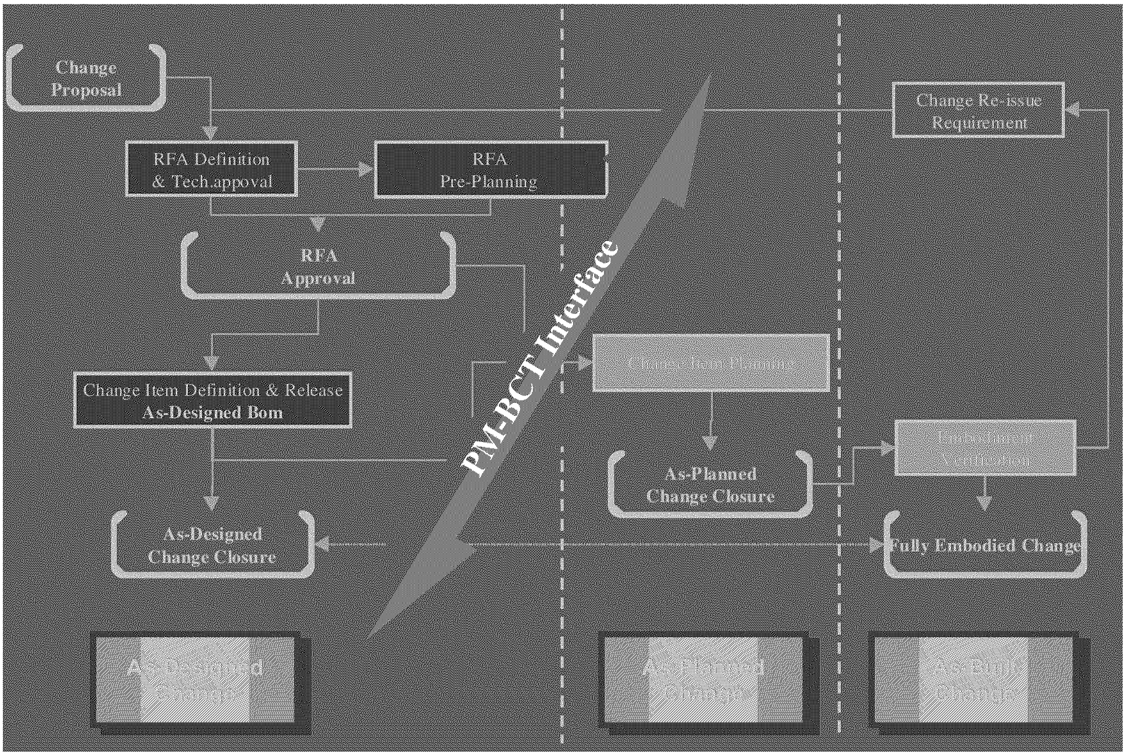

Figure 4 – Change Process Workflow

3.4 Advanced Information Management

PDM tools, and specifically the workflow functionality, can be used not only for releasing data, but also for Advanced Information Management.

Alenia PDM system has the capability to manage all information that is partially released during the product lifecycle and before the final part release. Not only the information related to an item have to be managed in an advanced way, but also the links between the items, so generating a preliminary Product Structure.

Two concepts have to be used in this approach:

- Maturity Stages
- Advance Information Release.

3.4.1 Maturity Stages

Maturity Stages represent the different levels of completeness related to the information (geometrical and non geometrical) which defines a part. The Maturity Stages have to be defined for each specific technology and incrementally. Therefore the usage of Maturity Stages enables an integrated schedule of the activities to be performed by the different company departments (Engineering, Manufacturing, Procurement, Quality, etc.) without waiting the final drawing/model release.

Each time a new issue for a specific maturity stage or a new maturity stage is reached, the new set of information automatically supersede the older and all the relevant company departments are notified with the change.

Inside Engineering departments, the Maturity Stages represent a tool which can be used in order to:

- monitor the progress of the Product Development process;
- improve visibility about the completeness reached by design information within the other company departments.

Inside Manufacturing Engineering, the Maturity Stages represent a way to operate in Concurrent Engineering and a tool by means of which it becomes possible to verify the level of completeness of the project evolution accordingly to the integrated schedule agreed inside Design Built Teams.

3.4.2 Advance Release Information

To complement Maturity Stages, another concept has to be used which defines advance but official release of information from Engineering towards Manufacturing departments.

Advance Release Information are themselves referred to a part being defined accordingly to its technological class as well as to their different usage in downstream processes (figure 6).

Three main kind of manufacturing activities can be defined which can/must start before the final official part release, those being:

- material purchase/supply
- tooling design
- Numerical Control part program design

The relationship between Maturity Stages and Advance Release Information can be summarized in the two following points:

- a minimum Maturity Stage exists which enables an Advance Information Release; this stage can vary with the part technological class and with the type of release
- the content of the package of information being released in advance can be equal to the minimum Maturity Stage content, a subset of it or a superset of it.

Managing advance information doesn't mean that data can be modified without any control. Anyway, procedures used for Advance Information Release as well as for their modifications have to be somewhat simplified compared to the final release ones.

Advance Information Releases are negotiated between Engineering and Manufacturing and result inside the Design Built Team schedule.

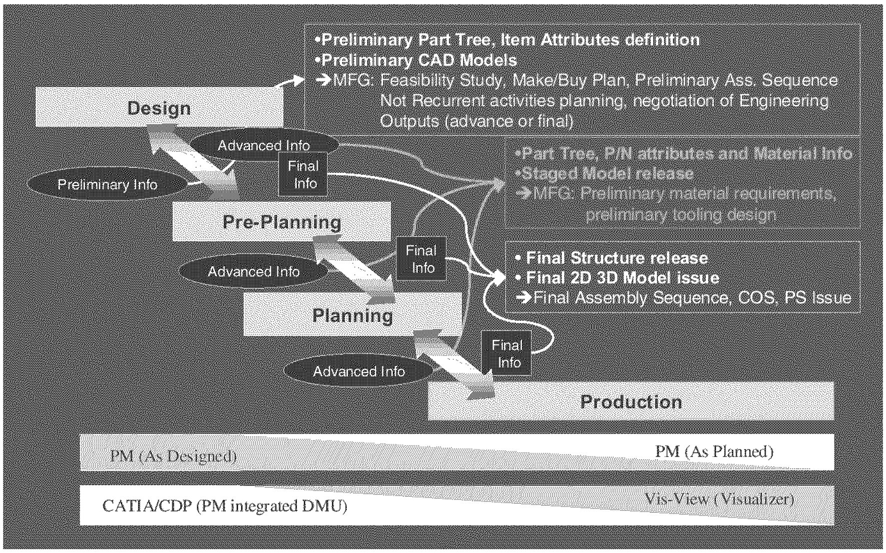

Fig. 6 – Advanced Release Information

3.5 Multi-site PDM Implementation

Alenia Aeronautica is a Company organised on different sites often working on the same programs. This implies that the same information must be visualised and used in parallel by various users belonging to different sites in a distributed environment.

To obtain this result a Wide Area Network (WAN) was implemented in the past years (figure 7). Nevertheless this situations can represent a tremendous problem if the data to be shared comprise thousands of CAD models with an average size of 1.5 Mb, because this means an unbearable effort for the WAN and a tremendous slowness for the users.

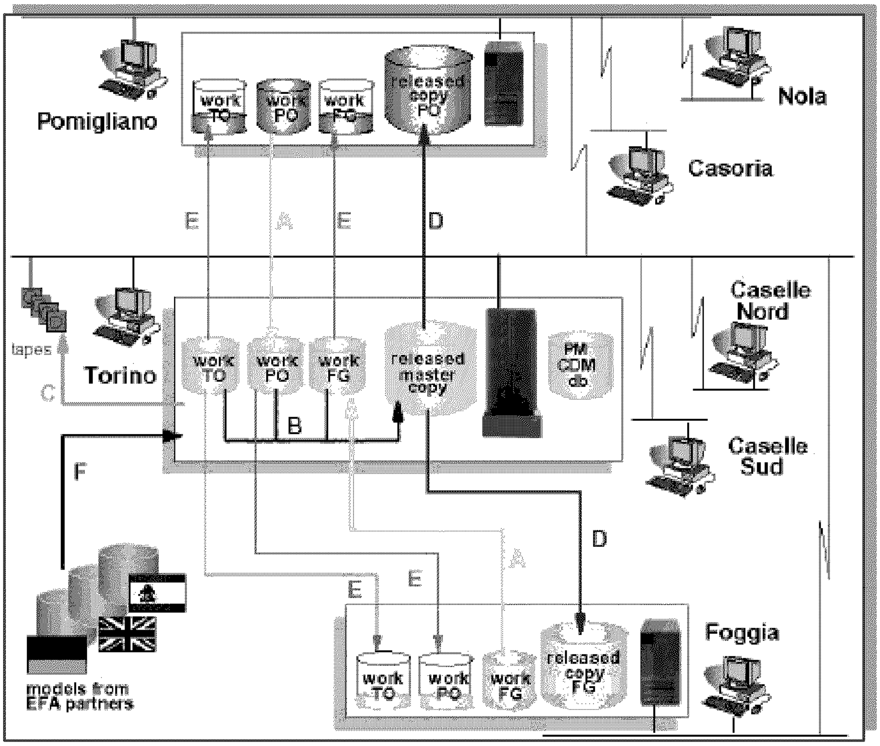

Figure 7 - Alenia Multi-Site PDM Implementation

The solution adopted, defined as “CAD data replication on remote sites”, is based on the following.

- Metadata (Part Numbers, material codes, model names, etc..) are stored on a unique master site (Torino for Eurofighter Typhoon program, Pomigliano for A380 program) and accessed by the users at each site directly via WAN
- The CAD models are replicated on three sites (Torino, Pomigliano and Foggia), accessed by the users on the site nearest to them, avoiding unnecessary traffic on the WAN and limiting it to the Local Area Network (LAN)
- The alignment between the three sites is asynchronous and is realised during the night by means of a replication regarding the CAD models created/updated during the day.

3.6 Configured Digital Mock-Up

The use of Digital Mock-Up (DMU) in Alenia as a basic tool for aeronautic design began in the middle of the ‘80’s, evolving and growing in terms of quality and quantity in line with the CAD systems and with IT capabilities. Therefore we moved from the part modeling initially using wire-frame methodology, then using wire-frame/surfaces or, as alternative, faceted solids, until to arrive to the exact solids. In parallel we passed from partial DMU’s dedicated only to some critical zones under a system/installation point of view, then to DMU’s simulating big aircraft components (e.g. an engine nacelle, a fuselage segment or a pylon) till to

reach the modeling of each single aircraft component, from the screw to the landing gear, generating in such a way a completely virtual aircraft.

For first and second generation DMU's we worked on some tens or, in the most complex situation, on a hundred of big CAD models which acted each one as a collector of the most considerable parts under a space allocation point of view for a certain aircraft zone or for a specific sub-group, disregarding not dimensionally significant parts. The preparation and the updating of the above models was entrusted to a Mock-Up "administrator" and only a small group of people was able to assemble them correctly for visualizing a certain aircraft configuration (i.e. the models valid only for Twin-seat or Single-seat).

However the above methodology is not applicable anymore in programs like Eurofighter Typhoon or A380, whether because the number of models to be handled would become in thousands, or because the number of DMU "clients" in the Company would increase exponentially, being no more limited to Design and Manufacturing Engineering, but extending to a lot of downstream departments, from the personnel dedicated to manuals preparation up to shop floor people.

The common requirement for all these new users is to access to DMU data without deep CAD knowledge and with the certainty of visualizing always the correct data for the required configuration.

Therefore, it appears the demand of a "configured" DMU that should permit the access to the models no longer as simple models but as virtual representations of physical parts, using as a key the relationships among the Part Numbers stored and configured in a product structure managed by means of a PDM. In the same database the PDM handles also the CAD models, viewed as Part Number reference documents, and, when existing, the part positioning in the space (figure 8).

To make use of a PDM system for managing the product data involves in any case the adoption of precise rules for data generation and administration, to be able to fully exploit its capabilities.

To cover the above requirement, since 1996 has been run in the Eurofighter consortium the DPA (Digital Product Assembly) Project, that is an initiative of the four EPC's (Eurofighter Partner Companies) applicable to the various phases of the program (development, production, product support), which embodies the usage of common CAD tools (CATIA, L-Cable) and selected applications as well as common standards and procedures to ensure data usability throughout the consortium.

The goal is to supply the basis to operate in true Concurrent Engineering, facilitating the information exchange among the EPC's and a simultaneous/controlled access to the product data.

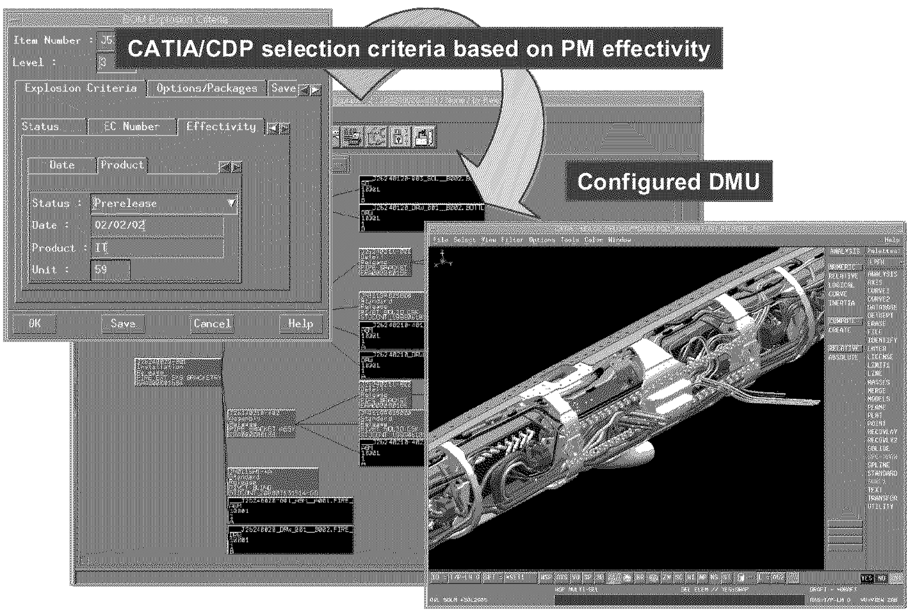

Fig. 8 – Example of access to the Configured DMU

With regard to DMU, the DPA key rule for the correct management of design data is "One part, one model, one drawing", which means that each Part Number has its dedicated 3D solid model, that the 2D model relevant to the drawing is separated from the solid model, and that, however, possible other models, when necessary, are represented in a dedicated file. Therefore it is possible to access to single models or, in case of 3D solids, to groups of tens or hundreds at once, taking into account also the relevant positions in terms of roto-translations previously stored.

The access to the CATIA models occurs starting from a graph in a bi-directional relationship with the models themselves. In other words it is possible to select a leaf representing a model on the graph and highlight on the CATIA window the corresponding solid or, on the contrary, by selecting a solid, to visualise which is the corresponding leaf on the graph.

3.7 Visualisation

The access to CAD data and to the Configured DMU by means of CDP/CATIA, even if it is precise and reliable, shows two limitations:

- the first is that most of the company users only need to consult the CAD data and do not have to contribute to their generation; consequently it is not convenient to train very many users in the CAD utilization for consultation purposes (buying also the necessary CAD licenses);
- the second is that it implies the availability of a quite expensive hardware as a Workstation, which is also not very much diffused in the company.

The introduction of the Visualiser just permits to eliminate the above limitations, satisfying the demand of those users which require a simple usage tool, a tool that works on an hardware universally diffused like Personal Computers.

The technology the Visualiser is based on is called "tessellation", that permits to reduce the weight of CAD data up to a magnitude factor, eliminating the CAD model of that information which are useful during the generation and modification phases but useless for consultation (for example the solid tree) and accepting an exact solid simplification; in effect the exact solid is treated as a faceted solid with an acceptable error margin (e.g. 0.2 mm). Through the tessellation the solid models are duplicated in "tessellated" format, while the 2D models are duplicated in CGM format (or other formats, for example the TIF one).

The Alenia selected tool, VisMockUp (or VisView, its "light" version), was interfaced with the PM/CDP world by means of a software written ad hoc nominated "PM Agent" (figure 9).

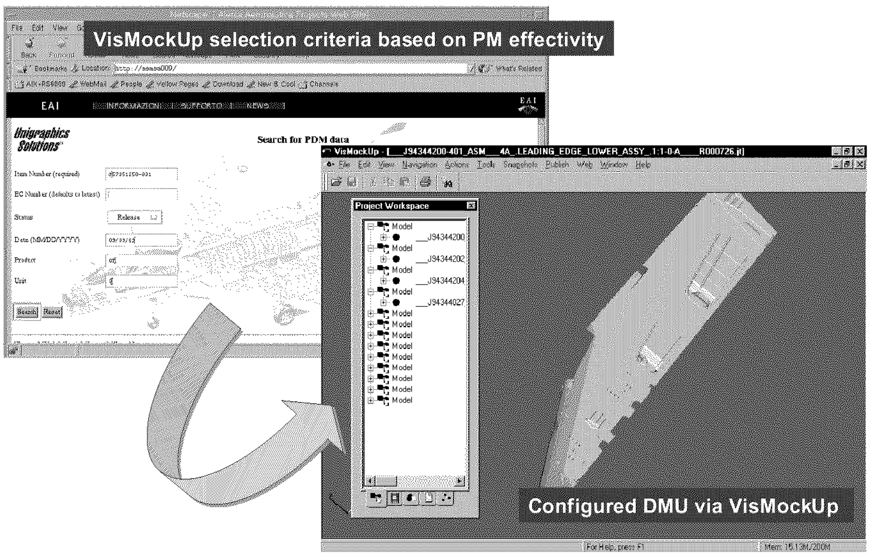

Fig. 9 – Integration between PDM and Visualiser

The CAD models generated during the day are tessellated night time maintaining an unambiguous/bi-directional relation between the tessellated data and the metadata related to the original models. In such a way, the day after all company users can access to the CAD data using a browser on PC, following essentially two methods:

- access to data of a single 3D or 2D model, with possibility of superimposing some models of the same type;
- access to relevant data for an assembly at whatever level of the product structure, with methods that are analogous to the CDP ones (but in this situation, the only accessible data are the 3D tessellated models).

With the second technique, it is really given to the user the possibility of manipulate a Configured DMU through VisMockUp also on PC.

3.8 Technical Publication and Training

Technical Publication and Training people are an “historical” customer of Product Structure and Configuration Management data, including all related attributes (e.g. material codes). Also in the past, starting from these data together with the traditional paper drawings, they were able to prepare documentation like Part Catalogues, Repair Manuals, Maintenance Manuals etc..

The most important added values given by Alenia PDM/CDP/Visualiser environment are the following:

- a unique and integrated environment for BoM and related attributes, Configuration Management information, Configured DMU and 2D Drawing Models;
- the possibility to use the Configured DMU directly to generate the pictures necessary for generate thousands of illustrations avoiding the old problem of moving from an “orthogonal projections” representation to an “isometric view” representation;
- the opportunity to generate short films to be used for training purposes.

4. Alenia Experience in Flight Simulation and Synthetic Environment

The history of flight simulation at Alenia Aeronautica dates back to 1961. A number of development and production standard flight simulators has been developed in-house since then, closely following technological advances in the field of computation, visual systems, and man-machine interfaces that have taken place since that time. From the first analogue calculators to state-of-the-art super-computers, things have changed quite dramatically and an ever increasing realism has been brought to more and more affordable systems.

The concept of Synthetic Environment (SE) was born from the consideration that the real time networking of several and different simulation systems enables the construction of an operational environment within which the variety, complexity, realism and inter-dependence of the external world are recreated, with an accuracy strictly derived by the simulation resources used.

One can generally refers to SE as an integrated simulation system consisting of the ensemble of live human operators, real systems and virtual models. Its goal is usually a real-time, distributed and interactive simulation exercise.

The availability of a SE offers several advantages: optimization of design, development, acquisition of weapon system processes; greater training effectiveness; greater mission rehearsal realism; lesser environmental impact during development and training.

4.1 Flight simulation facilities

Four flight simulators are available at Alenia Aeronautica in Torino: Eurofighter Typhoon in two versions, development and production standard, Alenia-Aermacchi-Embraer AM-X ground attack, and Alenia-LM Aero C-27J Spartan tactical transport aircraft.

The C-27J Simulator (figure 10) is presently used to support the development activities and flight testing of this evolution of the G-222 aircraft, and has also been conceived for training aircrew of the customers' Air Forces.

The AM-X simulator (figure 11) is the most senior within the department and has been used for training of more than a hundred Italian and Brazilian Air Force pilots, between 1989 and 1993.

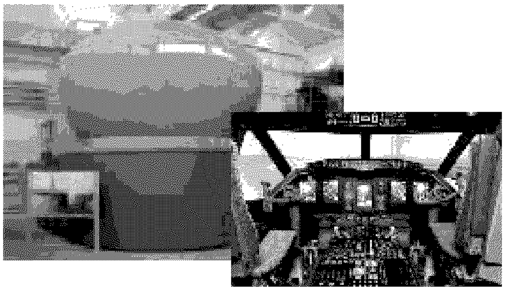

Figure 10 – C27-J Flight Simulator

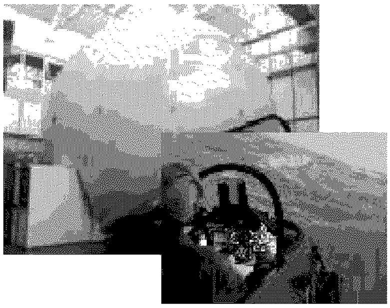

Figure 11 – AM-X Flight Simulator

The two Eurofighter Typhoon simulators (figures 12 and 13) are very tightly interdependent, since they have been devised as a twin dome facility able to provide air-to-air combat training capability. Most of the hardware components within the twin dome are linked by a high-speed optical link, a Versatile Module Equipment based reflective memory. While virtually all components of the production simulator are part of the loop, some important elements of the Development simulator remain on the local Ethernet. This is due to the incremental upgrade of existing simulators, but is not a hindrance to the efficient mutual exchange of status and position data provided by the optical link between the two simulators.

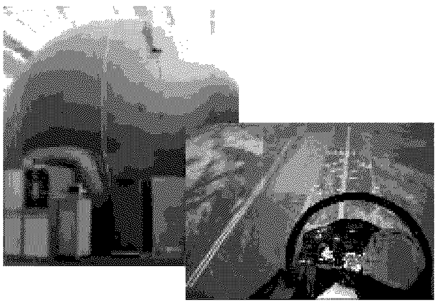

Figure 12 – Eurofughter development simulator

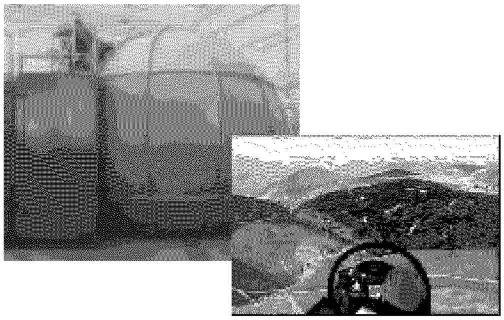

Figure 13 – Eurofighter production simulator

This type of link remains, in our opinion, a very efficient and cost-effective method to share information and memory segments at a local level. A similar architecture is also deployed in another optical loop, connecting the various elements of the C-27J simulator. By including in this loop the host computer for the older AM-X simulator, a direct exchange of status and position data between the two is possible. This second loop does enable formation flights, being connected to the twin dome reflective memory loop via high speed Ethernet link.

4.2 Simulation Synthetic Environment

A first-level SE is being set up within the Flight Simulation Center, formed by all available flight simulators (Eurofighter Typhoon development and production, C-27J, AM-X) in association with a virtual operational environment populated by a proprietary tactical scenario and several support tools. As more elements become available, they can be added to the SE.

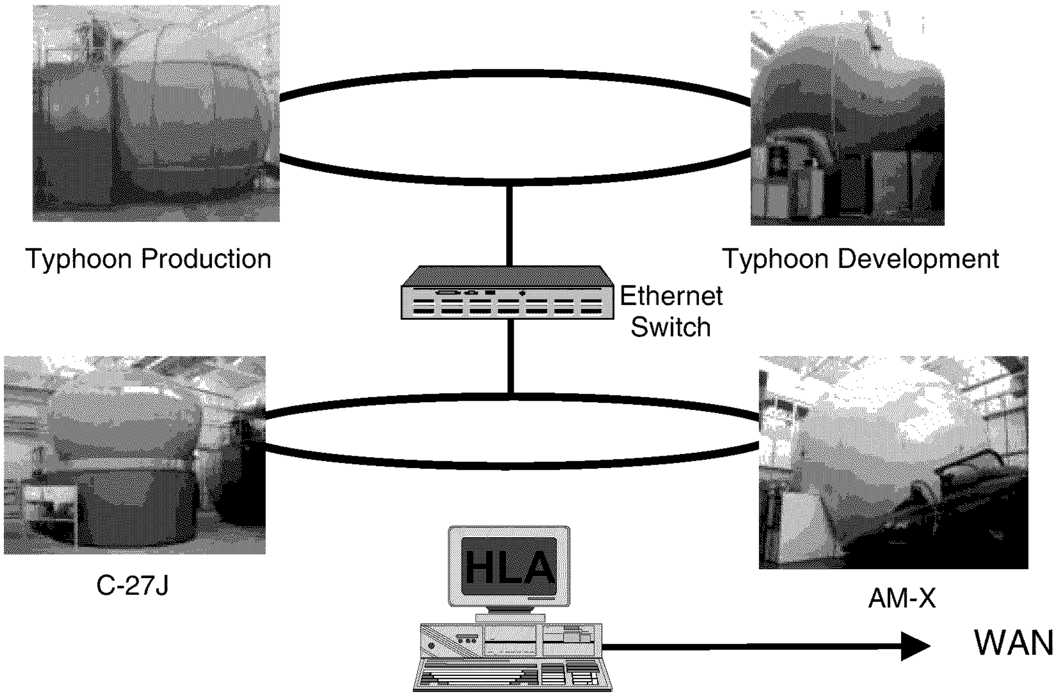

Figure 14 – Simulation Synthetic Environment diagram

With the importance of simulator networking in mind, High Level Architecture (HLA) technology is being gradually introduced by first linking all local resources among them (figure 14). A gradual extension of the network to external resources was subsequently started, and further projects involving international extensions are presently in their evaluation phases.

This activity consists in linking available simulators in real time, so that each simulator is aware of the others and can engage in joint operations with various degrees of interoperability.

Most flight simulators are legacy, i.e. have been designed for stand-alone operation with the main purpose of support, development and design activities. Typical SE applications require a substantial level of interoperability; as a consequence, a considerable amount of optimization and integration is needed.

The HLA is arguably the preferred methodology and software architecture used for such links today. Originated in 1995 by the Defense Modeling and Simulation Office (DMSO), a US Department of Defense Agency offering both the software and some minimal documentation free of charge, the HLA was created first as a fully functional version and disseminated as quickly as possible among the widest user-base possible.

On September 20th, 2000, the HLA has been voted on and instituted as IEEE 1516 standard, with specific purposes of promoting resource reuse and interoperability.

Alenia Aeronautica is presently evaluating HLA infrastructure as a tool to extend the local SE to one which includes distributed simulations.

With this respect, a dedicated machine is going to be included, which will be dedicated to HLA software. It will run the Run Time Infrastructure (RTI), the basic infrastructure allowing to implement the HLA standard, and it will host the HLA application responsible for representing the federate constituted by all entities connected by the ring. Its tasks will include publishing status data to the outside, subscribing to services available outside of the department, and providing a software layer to use for external interaction, according to the specifications of HLA.

It is worth to note that these iterative development steps for introducing HLA imply a number of challenges.

- Different data structure addressed by HLA (Object Oriented) and legacy simulations (structured programming).

- Need of expertise in both legacy systems architecture and new technologies/paradigms with a proper "system oriented" view.

Additionally, at the present stage of development, the use of DMSO-provided software might imply complications in that it has been developed with the aim of providing the users community with a workable, non-optimized mean to implement HLA. Therefore RTI performances have to be optimized towards each specific federation, either by trials or with automatic tools.

5. Towards a company-wide Synthetic Environment

The Distributed Environment described above is the kernel of a company-wide initiative encompassing tighter co-operation bonds between all departments in charge of the product design, i.e. weapon system design. The objective is the exploitation of a company Synthetic Environment intended as a pool of models, simulations, real equipment, with human actors in the loop, operating into a common virtual representation of the world. In this respect the SE should act as a common framework for providing consistency and concurrency to groups of previously detached processes. This environment would enable the visualization of complex military systems behavior (also considering changes to the systems or to their operating environment), and provides powerful means of communication between and within teams, therefore attaining the scope of Concurrent Engineering.

5.1 Development concept

The vision that would serve as a reference to develop the above concept comprises three main outposts that are also the key factor of Concurrent Engineering (figure 15).

- Organization: this area comprises organizational matters, functions and roles definition.
- Methods: standards, rules and recommended practices (applicable at international, government and company level) which has to be followed for appropriate work of the SE.
- Tools: Information Technology to support the activities as identified in the Organization area.

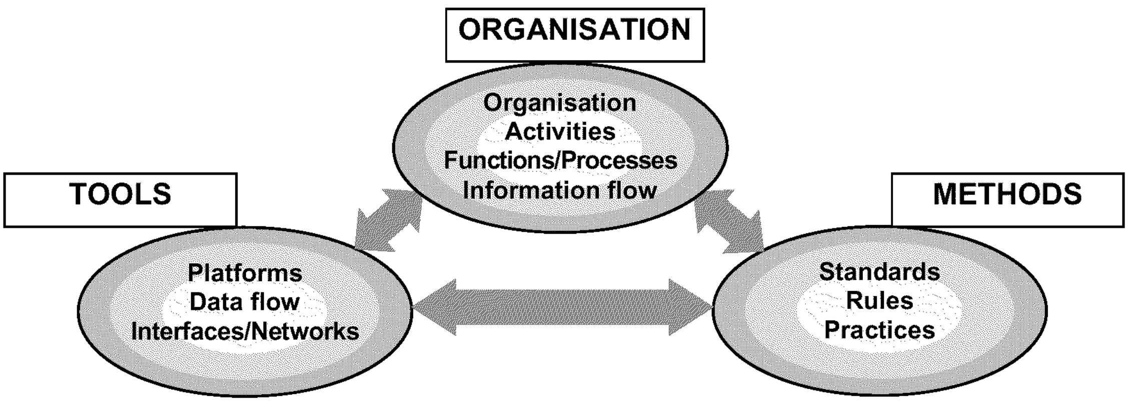

Fig. 15 - Concurrent Engineering and Synthetic Environment outposts

The introduction of the above architecture would imply a number of advantages.

- Improvement of the product quality and in-service support.
- Overall reduction of product lifecycle costs.
- Enhancement of the production process in terms of interfaces both inside the company and with Suppliers and Customers.

On the other hand, some issues could weaken or slow down the development of the above structure. One significant issue is cost: as a matter of fact, setting up of the above organization requires massive investments in terms of infrastructures, systems and human resources, in order to adapt according to program rules and industrial consortium rules, if any. This in turn has a significant impact on tools to be used and which shall allow proper data manipulation, tailoring and exchange. It is therefore evident that the introduction of a company SE requires balanced evaluation and an iterative development.

5.2 What next? First step: Functional Product Structure

Even if Concurrent Engineering, Virtual Product Management, Simulation and Synthetic Environment are good basis to move towards a Company-wide Synthetic Environment, the final result can be achieved only through a gradual approach, removing one obstacle at once.

Following the above philosophy, one of the possible improvements in the Virtual Product Management could be obtained in the information readability. In other words, using the Configured DMU and the Visualizer we have now a powerful and easy-to-use tool to navigate the Product Structure (PS) with its related data. The problem is that PS links are given following a Design/Manufacturing point of view that does not normally coincides with a functional point of view. For example, a fuel bracket riveted to a fuselage frame, in the As Designed/As Planned PS is linked to a structural installation regardless of the logical link between the bracket and the fuel pipe it constrains.

On the other hand, at the moment documents managed by our PDM are mainly related to the existing Part Numbers, therefore all the Engineering documents related to Aircraft Systems and Sub-systems which are not directly grouped under a part number, even if they could be managed inside the PDM as simple document objects, are not manageable in a complex and navigable structure. This means a limited readability of the system engineering data for non-specialist users and for the Customer.

The solution to the two above issues is the usage of a Functional PS (sometimes named as System Product Structure) which is defined as follows.

"Product Structure constructed using functional criteria for the classification and grouping of parts, to obtain a hierarchy of systems and subsystems, i.e. systems elements grouped by system functions (landing gear, controls, propulsion, radar, hydraulic, fuel, etc.), structural components grouped by structural function (i.e. fuselage, wings, horizontal tail), etc.. This Product Structure contains all the links with the related documentation."

Following this approach, documents like 3D models, drawing models, change records, etc. are managed in the Physical PS, while software and equipment specifications, qualification documents etc. are managed in the Functional PS. Zone collectors represent sub-system parts in a particular volume of the aircraft. Also the readability for Integrated Logistic Support customer is dramatically enhanced (figure 16).

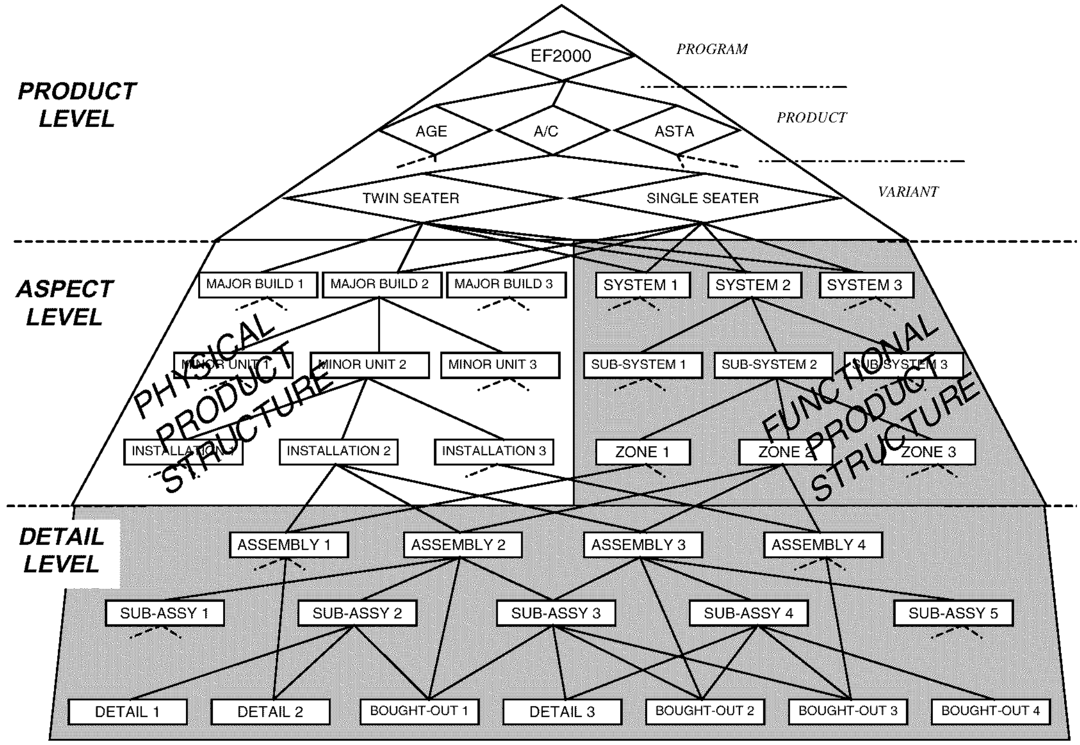

Figure 16 - Multiple Product Structure

The functional PS is therefore the natural framework through which SE resources can be integrated into the design process. At this level, entire functional structures within the project database can be accessed and visualized within the SE, which in turn can provide a physical model describing the behavior of the system or subsystem at study. Such a model will then be placed into the highly representative environment made available by virtual resources, and thereby tested under various evaluation criteria. This includes testing in specific atmospheric conditions, geographical configurations, or operational settings.

Man-in-the-loop mock-up validation is also an interesting possibility, given the real-time characteristics of most synthetic environments. If networked, this possibility is open also to remote users, with immense procurement/marketing advantages.

The advantages of the above solution are obvious, but unfortunately we have to take into account also the negative implications, i.e. the cost for creating and maintaining a conceptually new PS, the training for additional write access users and, in case of a program like Eurofighter Typhoon, which is already in an advanced phase, the additional cost for the data entry necessary to recover and reorganize the existing documents.

5.3 Research activities

While considering the above obstacles, evaluation of proper ways to further develop the vision is carried out through a number of activities, namely the European funded project ENHANCE, DIECoM and the WEAG Research and Technology Project 11.13.

- ENHANCE (Enhanced Aeronautical Concurrent Engineering) is a wide scope 3-year duration research project supported by the European Commission which started in February 1999 within the activities of the 4th Research Framework Programme. The main objectives of the project are: reduce the time-to-market, reduce the development cost and reduce the data management, conversion and transmission cost of European Aeronautical product development. Main focus of the project is on product engineering and design in an extended enterprise concept but there is activity devoted to product support, certification, contracts and multi-site team-working. Results include common processes, methods and tools to be used and exploited not only by the project partners themselves but also by the Supply Chain to improve

Concurrent Engineering practice for all levels of the Aeronautical Supply Chain. These take the form of 'Demonstrators' that show how these common processes, methods and tools meet their respective target requirements in terms of time, cost and quality.

- DIECoM (Distributed and Integrated Environment for Configuration Management) is a 2-year duration research project funded by the European Commission which started in September 2001 within the activities of the 5th Research Framework Programme. The main objectives of the project are:
  - to improve European Aerospace and Automotive industries capabilities in the Product and its associated customers' services Configuration Management;
  - to define an integrated process (procedures and rules) for Product Data Management (PDM), Software Configuration Management (SCM) and Electrical Data Management (EDM);
  - to validate the integrated process with two Pilot Demonstrators based on Commercial On The Shelf Information Technology tools. These demonstrators will be implemented with Enovia V5 and Websphere technologies respectively Dassault Systèmes and IBM products.
- RTP11.13 "Realizing the Potential of Networked Simulation in Europe" is a Western European Armament Group-funded project developed within Common European Priority Area 11 (CEPA) "Defense Modeling & Simulation Technologies". The project, which refers to the European Cooperation for the Long-term In Defense (EUCLID) framework and involves 22 companies from 13 European nations, started in November 2000 and has a duration of 36 months. The main goal of the program is to overcome the obstacles that prevent SE from being exploited in Europe, by developing a process and an integrated set of prototype tools intended to reduce the cost and time-scale needed to specify, create and utilize Synthetic Environments for collective training, defense planning, and system acquisition. In order to achieve this goal, a number of objectives have to be met, and in particular, it is necessary:
  - to determine and mitigate obstacles which prevent networked simulations from being exploited in Europe;
  - to provide processes and tools which will reduce the lifecycle of Synthetic Environment generation, execution and evaluation;
  - to set-up a European repository of simulation assets.

The experience described in the previous paragraph aims therefore at providing the basic technical infrastructure, while the above projects will serve to provide basic, international common-ground to implement Organization, Methods and Tools areas.

6 List of Acronyms

BoM	Bill of Material
CAD	Computer Assisted Design
CAE	Computer Assisted Engineering
CAM	Computer Assisted Manufacturing
CDP	CATIA Data - Product Manager Integration
CE	Concurrent Engineering
DBT	Design Built Team
DMSO	Defence Modelling and Simulation Office
DMU	Digital Mock-Up
DPA	Digital Product Assembly
EF	Eurofighter
EPC	Eurofighter Partner Companies
ERA	Engineering Release Authority

EUCLID	European Cooperation for the Long-term In Defence
HLA	High Level Architecture
IEEE	Institute of Electrical and Electronic Engineers
IT	Information Technology
LAN	Local Area Network
MCA	Manufacturing Change Alteration
MRP	Material Resources Planning
PDM	Product Data Management
PM	Product Manager
PN	Part Numbers
PS	Product Structure
RFA	Request For Alteration
RTI	Run Time Infrastructure
RTP	Research and Technology Project
SE	Synthetic Environment
VME	Versatile Module Equipment
WAN	Wide Area Network

Paper #7
Discussor's name F. Kafyeke
Author M. Fabbri

Q: You have outlined many tools that help improve the design to manufacturing process. Do you have any tools that help simulations of technical characteristics of the design (structural or aerodynamic analysis)?

A: Simulations are performed very early on various components of the designed product to make sure that they satisfy customer requirements [versus specific package tool identified].